DISCOVERY

Appraisal of heavy metal concentration and environmental impacts in selected textile dyeing effluents

Rafiqul Islam M[1], Shajedul Islam MD[2*], Jesmin Akter[1], Habibun Nahar[1], Tanzina Sultana[3]

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Author Affiliation:
[1]Hasanpur SN Government College, Comilla 3516, Ministry of Education, Bangladesh
[2]Government HSS College, Magura 6700, Ministry of Education, Bangladesh
[3]Gouripur Munshi Fazlur Rahman Government College, Comilla 3516, Ministry of Education, Bangladesh

[*]**Corresponding author**
Government HSS College, Magura 6700, Ministry of Education, Bangladesh
Email: t47207@nu.ac.bd

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ABSTRACT

By accumulating heavy metals through emissions of the textile dyeing effluents from the fast-growing textile and dyeing industries, environmental components such as soils, surface and groundwater may become polluted. The aim of the study was to assay the heavy metals in selected textile dyeing industrial effluents in the Rajshahi, Narshindi and Gazipur districts of Bangladesh. An atomic absorption spectrophotometer (AAS) was used to determine the concentration of selected heavy metals. The heavy metals Cr, Mn, Fe, Ni, Cu, Zn, Pb and Cd were studied in textile dyeing effluents in this study. Cr (0.0320 - 0.1334 ppm), Mn (0.1722 - 0.4119 ppm), Fe (2.891 - 4.2826 ppm), Ni (0.0032 - 0.1084 ppm), Cu (0.047 - 0.301 ppm), Zn (0.1648 - 0.3430 ppm), Cd (0.0045 - 0.1400 ppm) and Pb (0.0621 - 0.2900 ppm) were the metal concentrations of textile dyeing effluents for samples Ef1, Ef2, Ef3, Ef4 and Ef5, respectively. The results revealed that among the investigated metals, Fe, Cd and Pd were found at higher levels than the native and international standard values. The findings of the article will be enormously valuable in textile dyeing effluent treatment for building sustainable surface water management in industrial areas.

Keywords: Hazard, Industrial effluents, Metal concentration, Metal toxicity, Textile dyeing

1. INTRODUCTION

The safety of the environment and natural resources is a necessity for the right development of a country with subsequent economic growth. The features of manufacturing wastes vary from urban and commercial wastes (Islam, 2022). Massive amounts of organic, inorganic and organometallic chemicals are included in these production wastes, which are released from industrial sources and enter the food chain of living things. It is essential to remember that contaminants may have consequences that go much beyond the area in which they were emitted. Some contaminants linger in the environment for a long period after they are released.

Additionally, many contaminants only exist in very low quantities, meaning they have no immediate negative consequences. Long-term exposure to these quantities can cause disease (Bakraji and Karajo, 1999). Various textile dyeing industries that employ dyes and print use hazardous dyes. The health of humans and other environmental creatures is seriously impacted by these dyes. Industries are responsible for several environmental degradations, including soil erosion, air and water pollution and illnesses linked to soil degradation. As Bangladesh's economic growth has accelerated in recent years, so has its environmental degradation.

The harmful effects of Bangladesh's industrial development on air and water have not been given any consideration (Dan'Azumi and Bichi, 2010). Every day, the factories in Gazipur and Narshinshindi, Bangladesh, produce a significant quantity of effluents that are immediately dumped into nearby lands, agricultural fields, irrigation canals and surface water before ending up in the old Brahmaputra and Turag River (Islam et al., 2002).

The industrial effluents generated from the silk industries of the BSCIC area in Rajshahi fall either directly into the Padma or to the Barnai through some open channels via Beels (Hossain, 2018). As a result, environmental degradation is now endangering a huge number of peasants in the Narshinshindi, Gazipur and Rajshahi districts. This study aimed to assess the heavy metals in selected textile dyeing effluents. This heavy metal study may offer important information to address pollution issues.

2. MATERIALS AND METHODS

Sample Collection

Five types of textiles dyeing effluents were collected: Silk industry effluent, Ef1, Ef2 and Ef3 from the BSCIC area of Rajshahi and cotton and yarn dyeing effluent, namely, Ef4 and Ef5 from the Narsingdi and Gazipur districts, respectively. The effluent samples were collected separately in a one-liter plastic bottle that was prewashed with dilute HCl and rinsed three to five times with distilled water. The effluents were taken directly from the outlet of those industries. The effluent samples were filtered with Whatman No. 41 filter paper in another clean 1 L bottle. The effluent samples were wrapped in aluminum foil to prevent natural degradation by sunlight. Samples were labelled, sealed, transported to the laboratory and stored in a refrigerator at a temperature of about 4°C until the analyses were performed.

Sample preparation

Ninety-five (95) milliliters of the effluent sample were placed in a 100 ml beaker and 2 ml HNO_3 and 1 ml HCl acid were added. The beaker was then encircled with a watch glass and was reserved on a hot plate to evaporate the effluents close to aridness. The sample was then detached from the hot plate, permitted to cool at room temperature and levelled up to the mark with deionized water. Finally, the effluent samples were restrained with an atomic absorption spectrophotometer (AAS) for the analysis of heavy metals.

Analyses of Heavy Metals

The prepared effluent samples were investigated with an atomic absorption spectrophotometer (SHIMADZU AA-6300) furnished with a flame and graphite furnace atomizer. The textile dyeing effluent samples were inserted with an autosampler. Heavy metal deposits of textile dyeing effluents were measured from the standard curve that was arranged by the known related metal (element).

3. RESULTS AND DISCUSSION

Metals ascend from metal complex dyes and their derivatives, dye-baring agents, oxidizing agents and finishers in textile dyeing effluents (Heinfling et al., 1997; Zeiner et al., 2007; Mountassir et al., 2013). Several five-textile dyeing effluent samples from the Rajshahi, Gazipur and Narshingdi industrial areas in Bangladesh were analysed to determine the presence of heavy metals. This study analysed eight heavy metals in effluents, i.e., Cr, Mn, Fe, Ni, Cu, Zn, Pb and Cd and the concentrations of all investigated metals are included (Table 1).

Chromium (Cr)

Chromium (Cr) is a heavy transition metal. The Cr values of the effluents are 0.1334, 0.1334, 0.0907, 0.0320 and 0.0355 ppm for Ef1, Ef2, Ef3, Ef4 and Ef5, respectively (Table 1) (Figure 1). The concentration of Cr was within the permissible limit recommended by the DoE. These results suggested that this industry might use Cr-containing compounds such as chrome agents in dyeing processes. Hossain, (2018) conducted a study of effluent samples collected from the BSCIC industrial area of Rajshahi, where the mean value of Cr was 0.093 ppm, which was similar to the present study.

Table 1 Heavy metal concentrations in textile dyeing effluents

Heavy metals		Results					DoE Stnd.
		Ef1	Ef2	Ef3	Ef4	Ef5	
1	Cr	0.1334	0.1334	0.0907	0.0320	0.0355	0.5
2	Mn	0.1977	0.1977	1.2747	0.1722	0.4119	5
3	Fe	4.2328	4.2826	3.3493	3.6188	2.8911	2
4	Cu	0.0479	0.0479	0.301	0.0790	0.0470	0.5
5	Zn	0.2585	0.2740	0.3430	0.2047	0.1648	5
6	Pb	0.0621	0.0621	0.101	0.0086	0.2900	0.1
7	Ni	0.0087	0.0589	0.1084	0.0087	0.0032	1
8	Cd	0.0092	0.0089	0.0045	0.140	0.0098	0.05

Note: Concentration of metals is in mg/L (ppm)

Several researchers reported that the mean concentration of Cr in the textile industries was 16.9 to 35.2 ppm (Lokhande et al., 2011). Another study showed that the Cr concentration in Pickling and chrome-tanning effluents was approximately 2075 ppm, which was far above the present study results (Chowdhury et al., 2015; Islam and Mostafa, 2021).

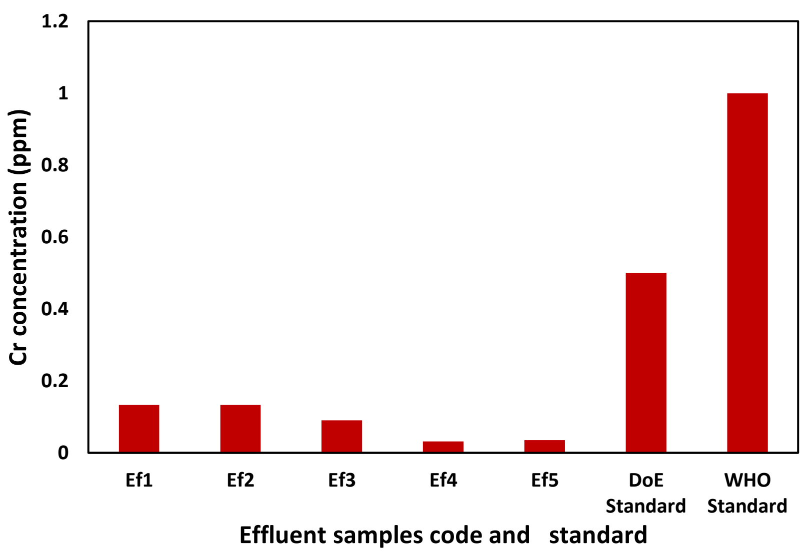

Figure 1 Cr concentration in textile dyeing effluents

The study results revealed that the concentration of Cr remained within the quality standard of the discharge effluent range. Cr is a danger to human health, mainly to people who work in the leather, textile and steel industries. Chromium is moderately toxic and responsible for lung cancer, nasal irritation, nasal ulcer, hypersensitivity reactions and contact dermatitis when entered into human bodies via dermal and inhalation routes (Aranda et al., 2010; Islam and Mostafa, 2021). The present findings were lower than the reported values, indicating less Cr poisoning in the study area.

Manganese (Mn)

Mn is reported to be vital in every animal species for biological activities. The concentrations of Mn in the textile dyeing effluents were 0.1977, 0.1977, 1.2747, 0.1722 and 0.4119 ppm for Ef1, Ef2, Ef3, Ef4 and Ef5, respectively, which were within the tolerable range of the DoE standard (Table 1) (Figure 2). The origin of Mn metal in the textile dyeing effluent was the dyebath stuff and textile wet processing industry.

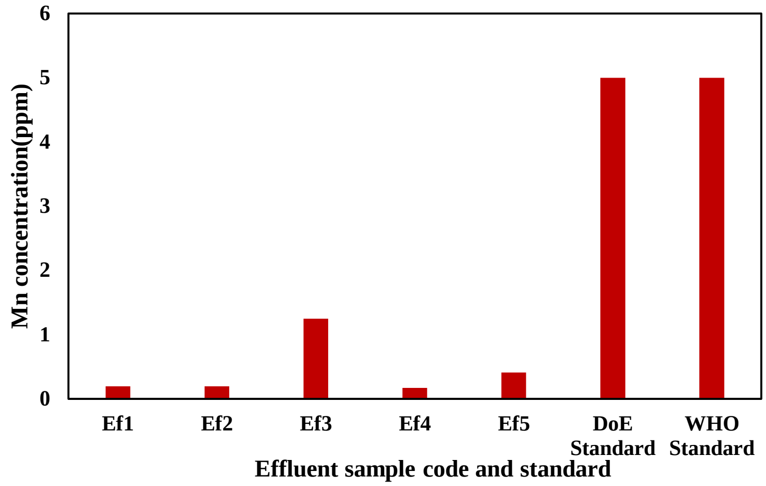

Figure 2 Mn concentration in textile dyeing effluents

A study report showed that the concentration of Mn varied from 0.68 to 0.72 ppm in the wastewater at the Kusthtia BSCIC industrial and Kumarkhali textile area in Bangladesh (Islam and Mostafa, 2022; Islam et al., 2016), which is similar to the present study results. Hallucinations, memory impairment, disorientation and emotional instability are also caused by Mn overdose (Gupta and Gupta, 1998). So, the effluents of the present research were free of Mn pollution.

Iron (Fe)

Iron is one of the most abundant trace elements found in the Earth's crust. The Fe concentrations of the samples were 4.2328, 4.2826, 3.3493, 3.6188 and 2.891 ppm for Ef1, Ef2, Ef3, Ef4 and Ef5, respectively, which were higher than the national quality discharge standard limits for textile dyeing effluent (Table 1) (Figure 3).

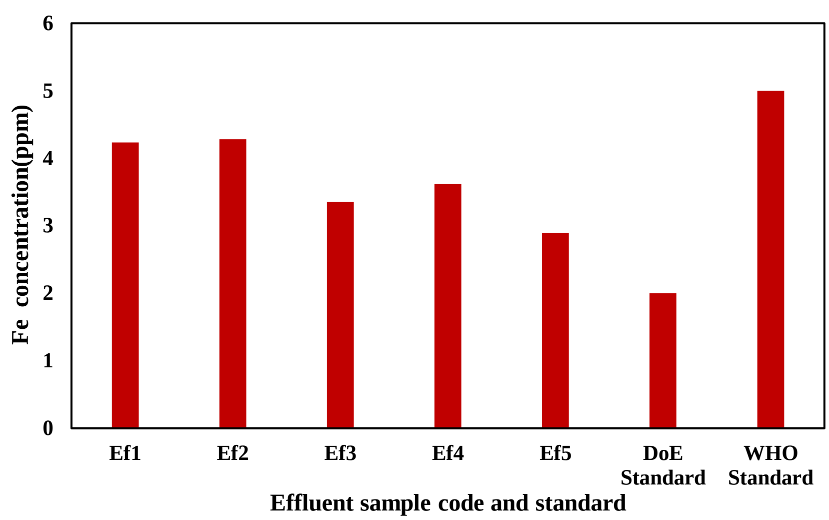

Figure 3 Fe concentration in textile dyeing effluents

The source of iron may be various classes of dyes used in the textile and silk industries. Similar results were found by Ahmed et al., (2019) from a study on the textile effluents of the DND area, Bangladesh, where the concentration of Fe varied from 0.238 to 1.45 ppm. Several investigators illustrated that the concentration of Fe in textile dyeing effluents was about 12.8 ppm (mean) (Lokhande et al., 2011) and in the range of 0.92 to 21.12 ppm (Joshi and Shrivastava, 2015), which was similar to the present study.

The presence of a high concentration of iron may increase the hazard of pathogenic organisms, as most of these organisms need Fe for their growth. Overdosing of Fe is potentially hazardous and plays a vital role in causing diabetes and hemochromatosis lung and heart diseases (Islam and Mostafa, 2021; Sobana and Swaminathan, 2007). Therefore, it is evident that the effluents of the present study area were not free of iron pollution based on the Fe concentration.

Nickel (Ni)

Nickel is a naturally occurring element widely used in many usages. The concentrations of nickel in the textile dyeing effluents were 0.0087, 0.0589, 0.1084, 0.0087 and 0.0032 ppm for Ef1, Ef2, Ef3, Ef4 and Ef5, respectively (Table 1) (Figure 4), which are lower than the permissible limit of wastewater discharge standards according to the DoE, (2008) and the Ni concentration was also lower than that in Pakistan (0.67 ppm) reported by Ali et al., (2009). It is a nutritionally essential trace element for humans and other animal species and plants but is toxic at high concentrations (Hasan et al., 2019).

Ship trip effluents, industrial applications and chemical industries are sources of Nickel (Islam and Mostafa, 2021; Baysal et al., 2013). Manekar et al., (2014) stated that the Ni concentration of textile effluents in western India varied from 0.08 to 0.13 ppm, which was comparable to the present study.

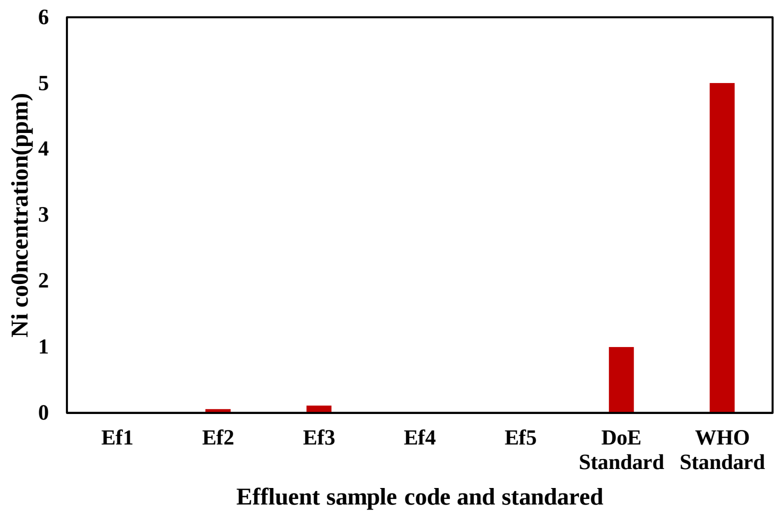

Figure 4 Ni concentration in textile dyeing effluents

The most adverse harmful health effects from exposure to Ni include lung fibrosis, cardiovascular and kidney diseases and cancer of the respiratory tract (ATSDR, 2005). Higher Ni concentrations are responsible for asthma, conjunctivitis, inflammatory reactions, nickel-containing prostheses and implants (Islam and Mostafa, 2021; Nielsen et al., 1999). Therefore, it can be stated that the affluent nature of the study was free from Ni contamination.

Copper (Cu)

Copper is a vital trace element that plays a substantial role in the biochemical processes of all living organisms and is essential for human health. The obtainable range of copper concentration in the textile effluents was 0.0479, 0.0479, 0.301, 0.0790 and 0.0470 ppm for Ef1, Ef2, Ef3, Ef4 and Ef5, respectively (Table 1) (Figure 5).

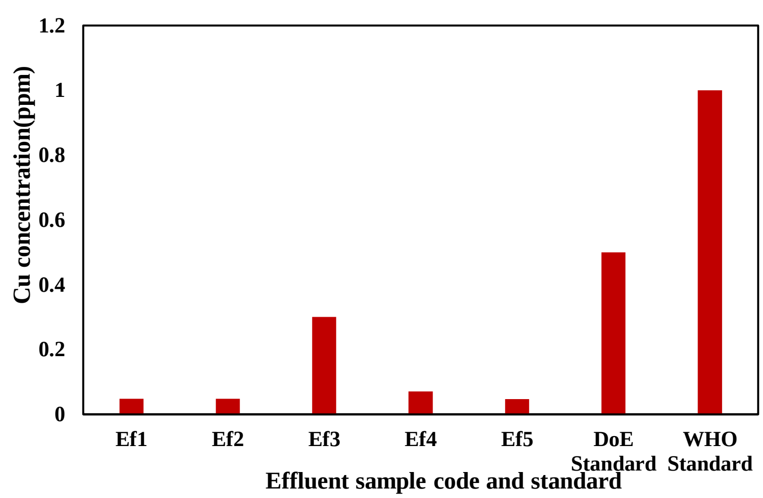

Figure 5 Cu concentration in textile dyeing effluents

Cu is a vital material to human nutrition as a constituent of metalloenzymes due to its capacity as an electron donor or acceptor (Deepali and Gangwar, 2010). Although humans can handle a proportionally large concentration of Cu, too much of it can cause eminent health problems (Baysal et al., 2013). Nevertheless, at high concentrations, it may be responsible for intentional irritation, anaemia, kidney and liver damage, stomach and anaemia (Imtiazuddin et al., 2014).

Cu is noxious to aquatic flora at concentrations under 1 ppm, while a concentration near this level can be poisonous to some fish (Islam and Mostafa, 2022; Nergis et al., 2005; Tuzen et al., 2008). The effluents of the selected textile dyeing effluents were free from pollution based on the Cu concentration of the present findings.

Zinc (Zn)

Zinc is a trace element that is essential for human health. Zinc is a vital micronutrient that participates in plant physiological functions and has beneficial effects on plant growth, but water may be contaminated with large quantities of Zn present in the effluents of industrial plants. The zinc concentration of effluent samples varied from 0.1648 ppm to 0.3430 ppm, which is lower than the national quality discharge standard limits for effluents (Table 1) (Figure 6).

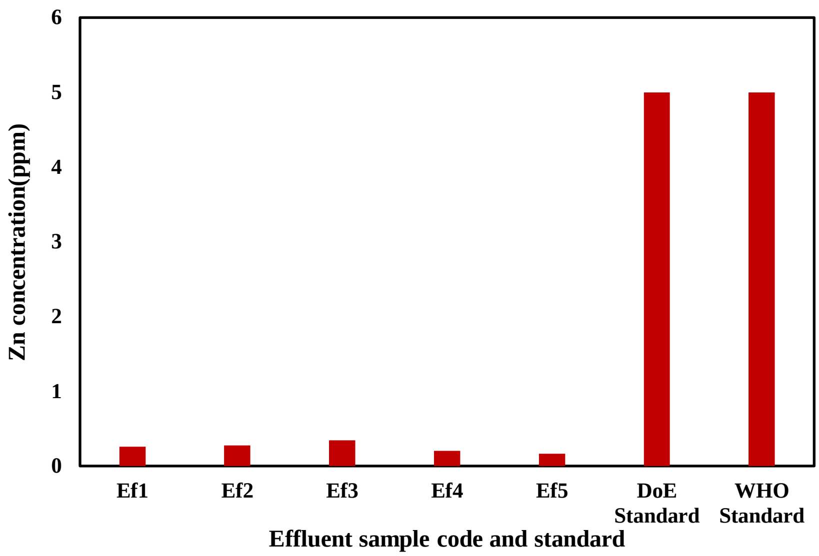

Figure 6 Zn concentration in textile dyeing effluents

The Zn concentration in effluent rises owing to the usage of chemical impurities and the method of viscous rayon fibres in textile industries (Hussian et al., 2004). A shortage of Zn can cause birth defects (Islam and Mostafa, 2021; Wuana and Okieimen, 20). Ahmad and Goni, (2010) conducted research and concluded that the Zn concentration of wastewater ranges from 0.49 to 1.69 ppm at DEPZ. Momtaz et al., (2012) also described a study result that the concentration of Zn was in the range of 0.134 to 0.308 ppm in the above industrial area, which is very close to the present findings of the study. Research work on textile dyeing effluents in the DND area, Bangladesh, observed that the zinc concentration of the textile effluents ranged from 0.021 to 0.204 ppm, which was similar to the present research (Ahmed et al., 2019).

Another study conducted by Lokhande et al., (2011) stated that the average concentration of Zn was 27.1 ppm in textile effluents collected from the Tajola industrial estate of Mumbai, India, which was similar to the present study. A high concentration of Zn in water is most harmful to aquatic life during the early life stages (Imtiazuddin et al., 2014; Islam, 2022). Some fish can accumulate Zn in their bodies when they live in Zn-contaminated waterways. When Zn enters the bodies of these fish, it can biomagnified up the food chain (Wuana and Okieimen, 2011). The present findings showed that the Zn concentration in the effluents has no hazard to the environment.

Lead (Pb)

Lead is one of the oldest metals known to humans. Lead is not an essential element, but as a well-known metal toxicant, its effects have been extensively reviewed compared to the effects of other heavy metals. In the present study, the concentration of lead in the

textile dyeing effluents was found to be 0.0621, 0.0621, 0.101, 0.0086 and 0.2900 ppm for Ef1, Ef2, Ef3, Ef4 and Ef5, respectively (Table 1) (Figure 7).

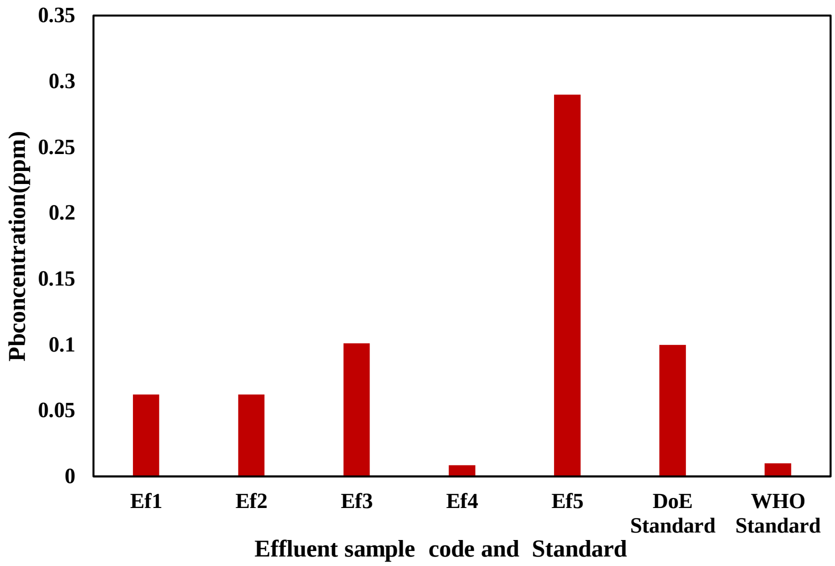

Figure 7 Pb concentration in textile dyeing effluents

Lead is discharged into the surface water through paints, solders, pipes, building materials, gasoline, etc. (Wuana and Okieimen, 2011). The most stable forms of lead are Pb^{2+} and lead hydroxy complexes. The concentration of Pb metal was lower than the national quality discharge standard limits for textile dyeing effluents except for the concentration of Pb in samples Ef3 and Ef5, which was higher than the standard limit of DoE as stated by Dey and Islam, (2015). This may be due to the use of Pb-bearing dyes and other chemicals by the relevant textile industries.

A report on textile industrial effluents in the Kushtia BSCIC and Kumerkhali textile mill areas of Bangladesh showed that the concentration varied from 0.0045 to 0.0085 ppm (Islam et al., 2016). The concentrations in the study area were found to be similar to the results of the Kushtia BSCIC area. Another study conducted by Manekar et al., (2014) on the effluents of a textile park located in western India observed that the Pb concentration varied from 0.11 to 0.12 ppm, which partially supported the findings of the present study. The toxicants and environmental effects of oregano lead complexes are noteworthy because of the widespread use and distribution of tetraethyl lead (TEL) as a gasoline additive (Wuana and Okieimen, 2011).

Lead is a naturally occurring element that is toxic to both the central and peripheral nervous systems, including neurological and behavioural effects (WHO, 2022). It is generally a toxicant that accumulates in the skeleton and infants' children up to 6 years of age and pregnant women are most susceptible to its adverse health effects. Lead can cause serious injury to the brain, nervous system, red blood cells and kidneys (Baldwin and Marshall, 1999). Exposure to lead produces various deleterious effects on the hematopoietic, renal reproductive and central nervous systems, mainly through increased oxidative stress (Flora et al., 2012). The study showed that there is a lower possibility of causing harm due to Pb poisoning in the areas.

Cadmium (Cd)

Cadmium is considered a very toxic trace metal and nonessential element because of its extremely long half-life. Together with Hg, Pb and Cd are two of the three major heavy metal poisonings and are not known for their essential biological functions. Cd is a nonessential element. It is both bioavailable and toxic. Its interference with metabolic processes in plants can bioaccumulate in aquatic organisms and enter the food chain (Adriano, 2001). The concentration of Cd in the effluents was obtained to be 0.0045 to 0.140 ppm for Ef1, Ef2, Ef3, Ef4 and Ef5, respectively, which are within the permissible limit of the DoE standard (Table 1) (Figure 8).

A report published in the Indian industrial state of Mumbai showed that the concentration of Cd was 23.3 ppm to 23.8 ppm in effluent samples collected from textile industries (Lokhande et al., 2011; Islam et al., 2023). Cadmium is both bioavailable and toxic. Its interference with metabolic processes in plants can bioaccumulate in aquatic organisms and enter the food chain (Adriano, 2001). A recent study showed that the mean concentration of Cd was almost five times higher than the WHO limit in tube well water in

Rajshahi city (Mostafa et al., 2017). Another study conducted by Joshi and Shrivastava, (2015) illustrated that Cd concentration was detected in the range of 0.014 to 0.56 ppm in printing and dyeing effluents of Maharastra, India.

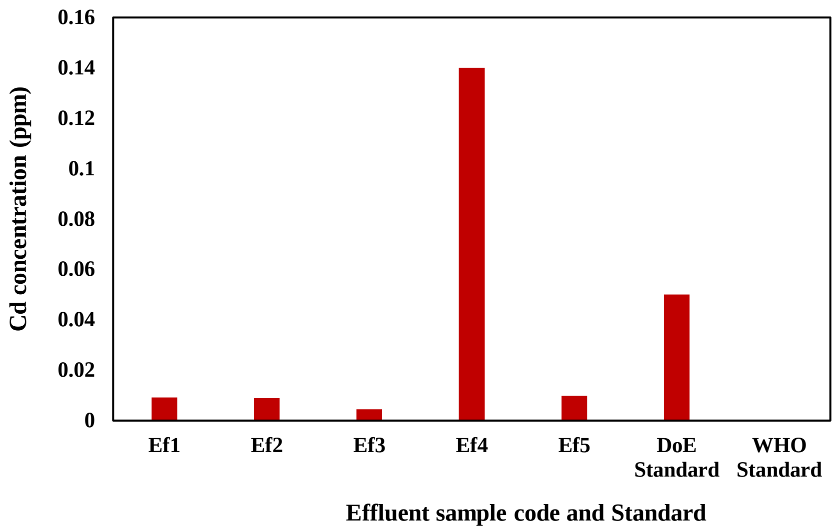

Figure 8 Cd concentration in textile dyeing effluents

Vegetables and fruits that contained a high concentration of trace elements such as Cd, Cu and Pb increased the probability of upper gastrointestinal cancer (Turkdogan et al., 2003). Long-term consumption of Cd increases the rate of kidney failure, softening of bones (Ahmed et al., 2019; Jihen et al., 2008) and prostate cancer (Gray et al., 2005). Food intake and tobacco smoking are the main routes of Cd poisoning in the human body (Manahan, 2002). The observations of the studies were similar to those of the present study. The present study showed a comparatively lower Cd concentration in the textile effluents less treated to the environment.

4. CONCLUSION

The findings unambiguously demonstrate that heavy metals such as Cr, Mn, Fe, Ni, Cu, Zn, Pb and Cd, which were present in the collected samples of the untreated textile dyeing effluent, caused problems. The heavy metal concentrations in the effluent samples were found in the range of 0.0320 to 0.1334, 0.1722 to 0.4119, 2.891 to 4.2826, 0.0032 to 0.1084, 0.047 to 0.301, 0.1648 to 0.343, 0.0045 to 0.14 and 0.0621 to 0.29 ppm for Cr, Mn, Fe, Ni, Cu, Zn, Cd and Pb, respectively. The concentration of heavy metals in textile dyeing effluents was within the discharge of the permissible limit of the effluents of the Department of Environment, Bangladesh (DoE, BD), except for Fe, Cd and Pb.

The concentration of iron in the effluents was higher than the DoE and BD standard limits due to the use of different iron-containing dyes and mordants in wet and dyeing processes. The concentration of Pb in samples Ef3 and Ef5 was higher than the standard limit of DoE and BD, indicating that the discharge effluents were more concentrated. Therefore, it is suggested that a thorough investigation be done to determine the harshness of the issue.

Informed consent

Not applicable.

Ethical approval

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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